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Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
Bianchi, F., Santurette, S., & Dau, T. (2014). *Pitch coding of complex tones in the normal and impaired auditory system*. Poster session presented at International Hearing Aid Research Conference 2014, Lake Tahoe, United States.

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Pitch coding of complex tones in the normal and impaired auditory system

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Introduction

Recent physiological studies suggested that sensorineural hearing loss (SNHL) can lead to an enhancement of temporal envelope coding which may arise from a variety of factors, e.g., broader auditory filters, a reduction of cochlear compression due to outer hair cell damage (Kale and Heinz, 2010; Henry et al., 2014) and altered auditory-nerve response temporal dynamics (Scheidt et al., 2010). The aim of the present behavioral study in humans was to clarify if an enhancement of temporal envelope coding affects the pitch perception of hearing-impaired (HI) listeners. An **amplitude-modulation detection task** and a **pitch discrimination task** were performed in normal hearing (NH) and HI listeners.

1. Pitch discrimination

Method

Pitch discrimination of complex tones was measured via difference limens for fundamental frequency (F_0 DLs). Complex tones were filtered in a **low** (LF: 0.3-1.5 kHz) and **high** (HF: 1.5-3.5 kHz) frequency region, with components added either in sine or random phase.

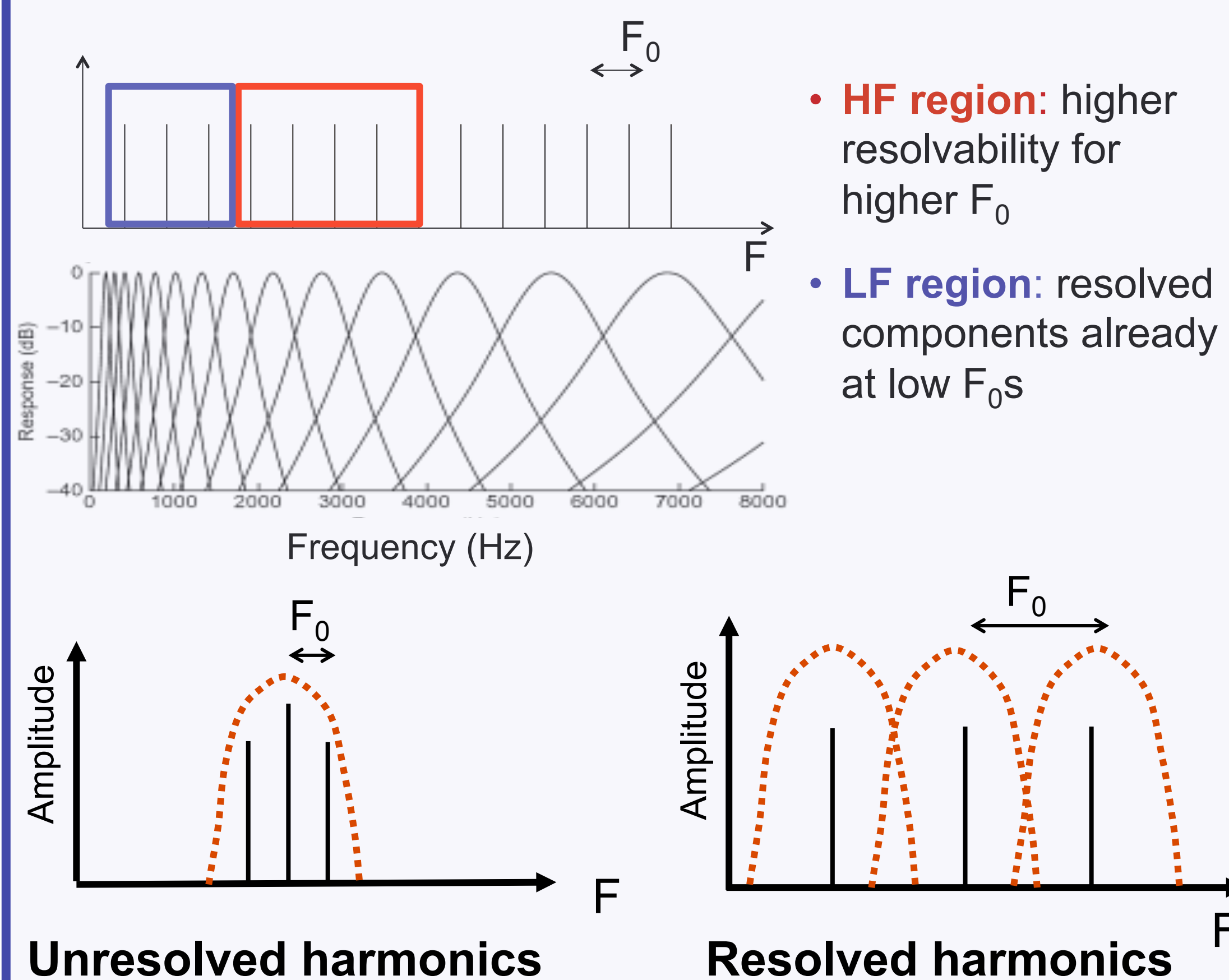


Figure 1. Resolvability of a complex tone filtered in a **low** and **high** frequency region, as a function of F_0 .

Results F_0 DL

14 normal-hearing listeners

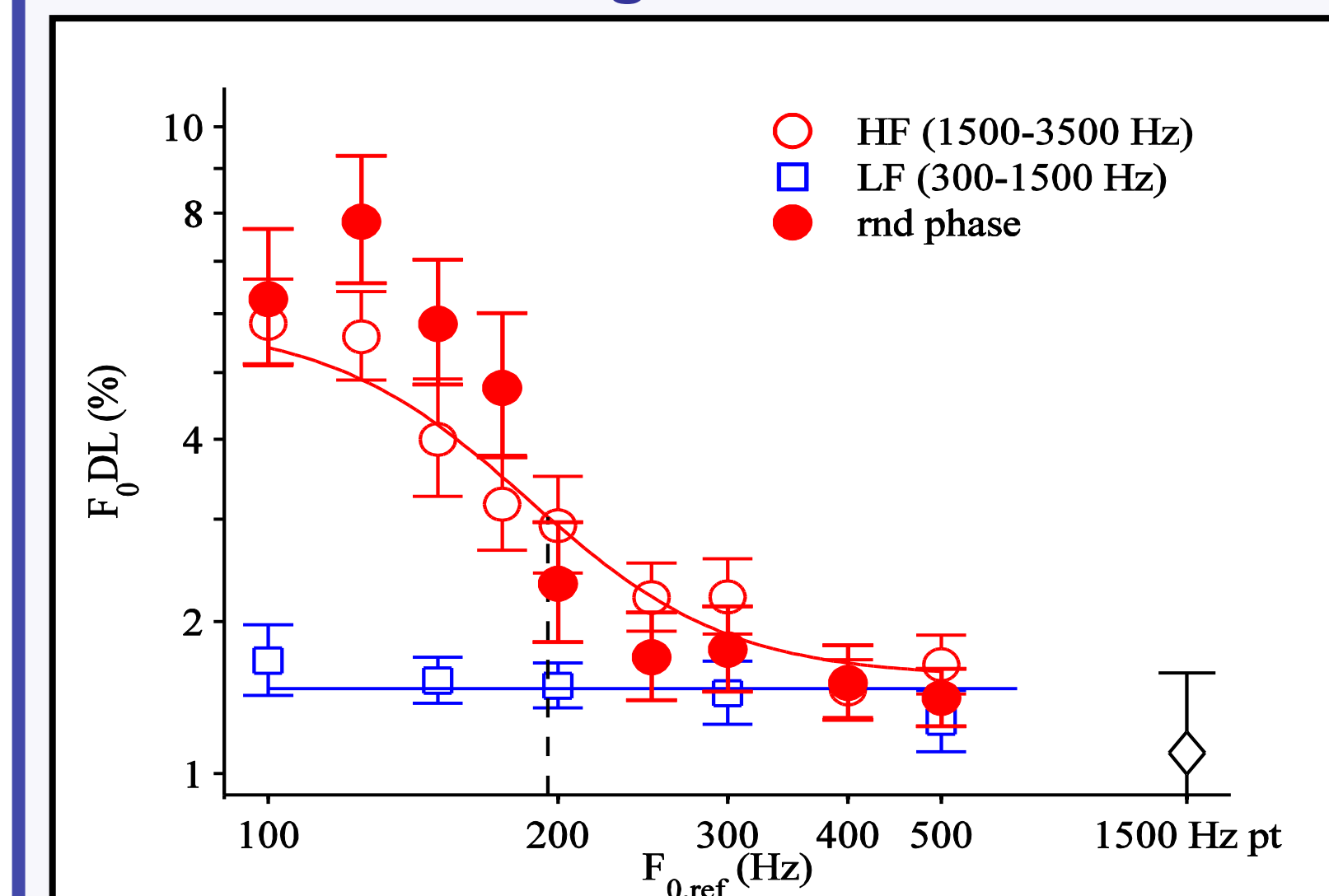


Figure 2. Mean F_0 DLs for 14 NH listeners (open symbols: sine phase; closed symbols: random phase).

- HF region: performance improves with increasing F_0 (F_0 DL_{max}: 6%)
- LF region: pitch discrimination independent of F_0 (F_0 DL_{min}: 1.7%)
- resolvability: $F_0 > 200$ Hz

5 hearing-impaired listeners (30-60 dB HL between 1.5-4 kHz)

HI group 1

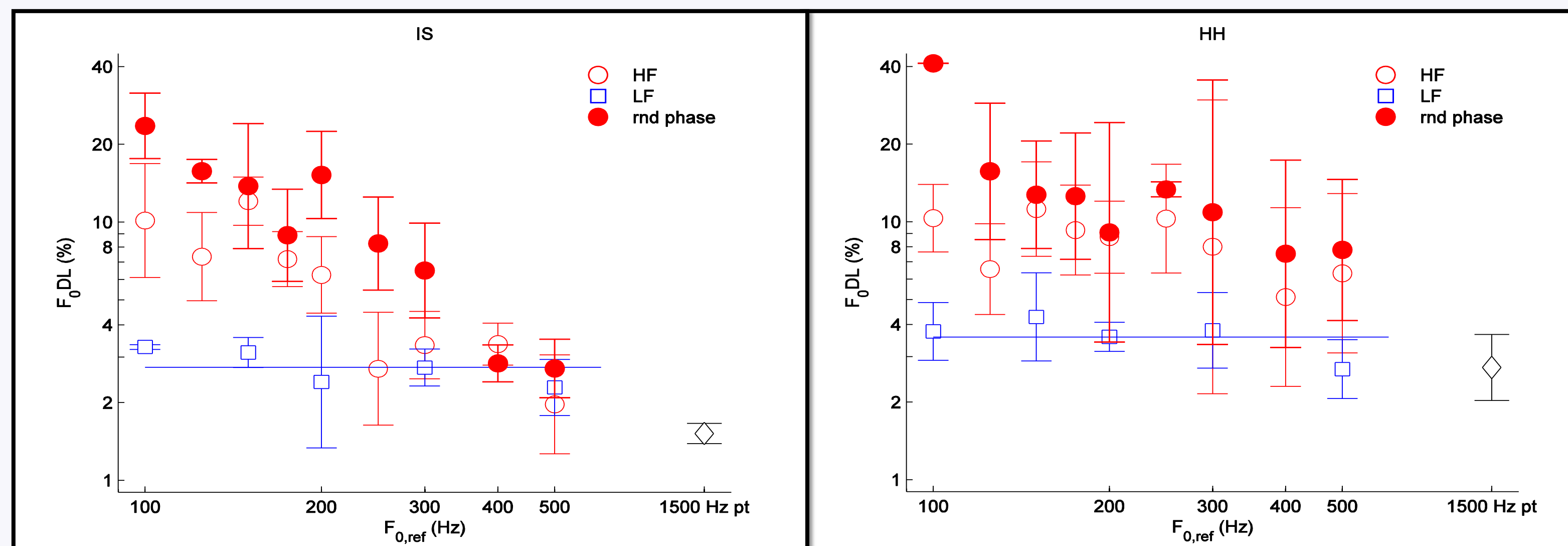


Figure 3. Individual F_0 DLs for 2 HI listeners (open symbols: sine phase; closed symbols: random phase).

- similar trend as NH, but resolvability for $F_0 \geq 400$ Hz
- higher F_0 DL_{min} (3-4%) and F_0 DL_{max} (10% for sine phase)
- HI group 2**
- low F_0 s: better than NH for sine phase (2-5%)
- med F_0 s: worsening in performance
- at 500 Hz: components begin to get resolved

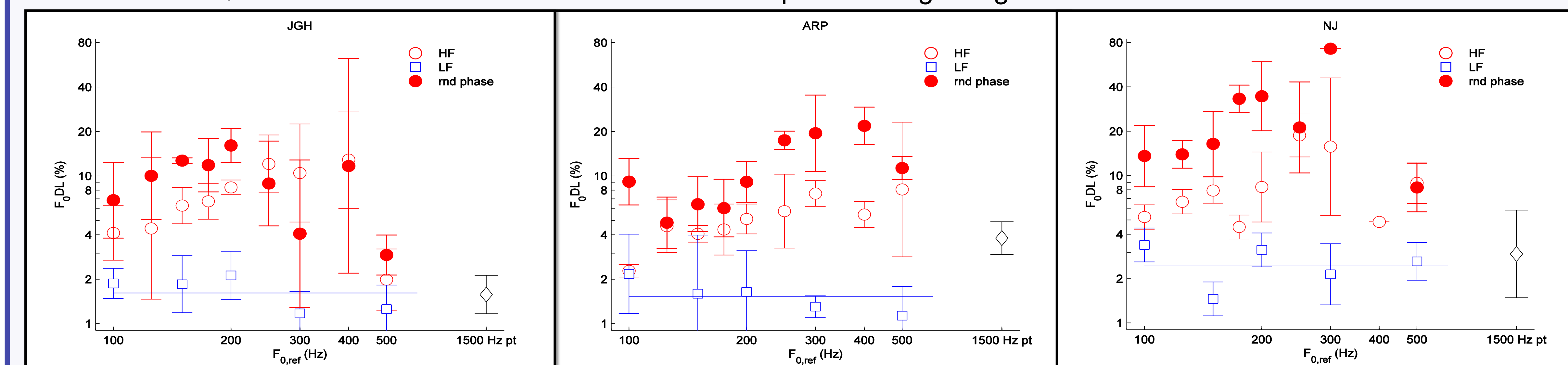


Figure 4. Individual F_0 DLs for 3 HI listeners (open symbols: sine phase; closed symbols: random phase).

2. Amplitude modulation detection

- measure of the ability to detect amplitude modulations for sinusoidal carriers ($f_c = 2$ kHz, $f_m = 25$ -1500 Hz) via temporal modulation transfer function (TMTF).

Results TMTF

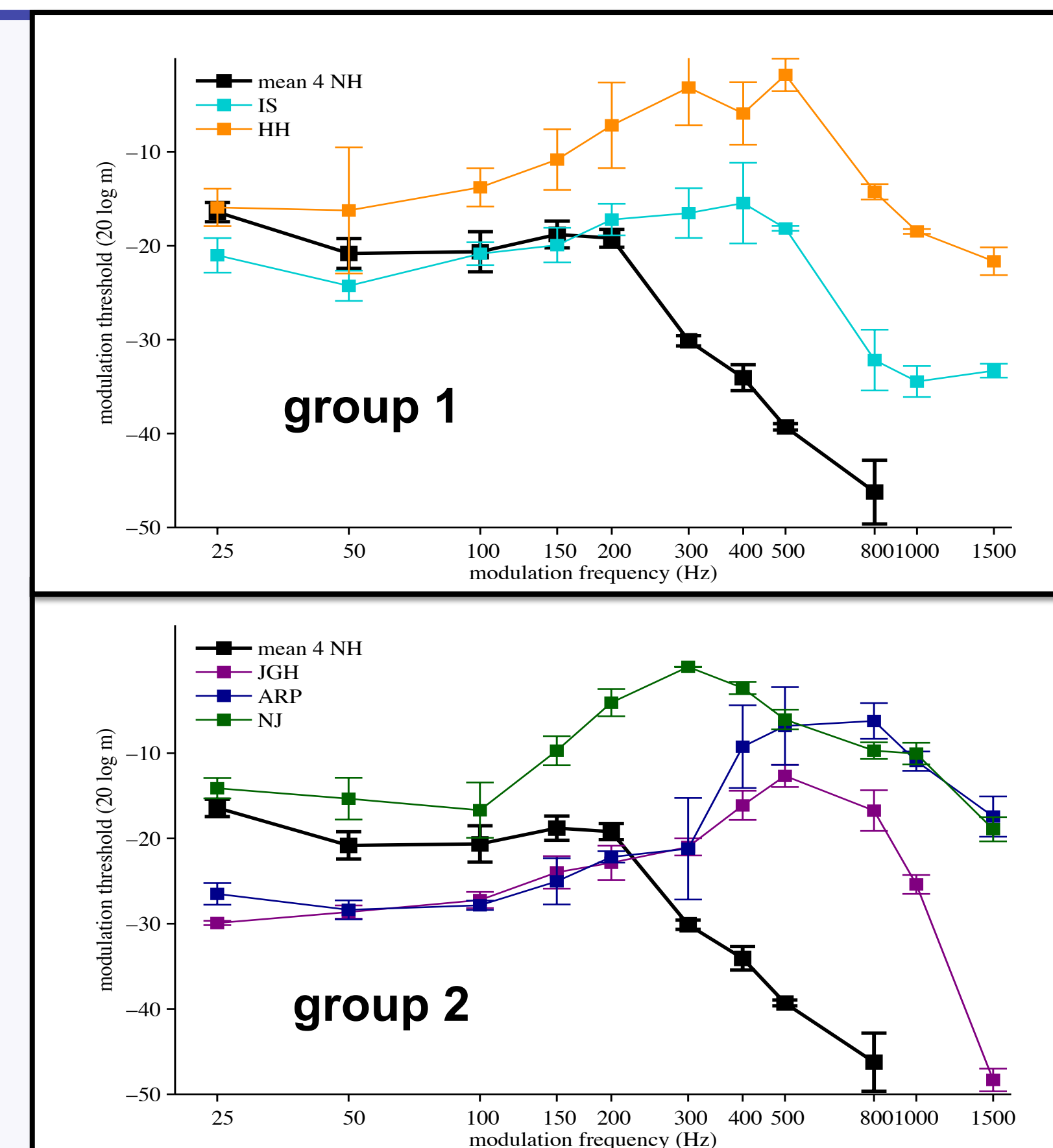
HI group 1 vs NH

- similar (IS) or worse (HH) performance than NH
- threshold independent of f_m up to 400-500 Hz (IS), then it decreases with f_m

HI group 2 vs NH

- low F_0 s: lower threshold than NH (JGH and ARP) -> not more components
- medium F_0 s: worsening in performance ("sluggishness")

Figure 5. Mean TMTF for 4 NH (black squares) and individual TMTF for 5 HI listeners (colored symbols).



Comparison F_0 DL and TMTF

- enhancement at low F_0 s and "sluggishness" in both F_0 DL and TMTF (enhancement occurred for 2 HI listeners).

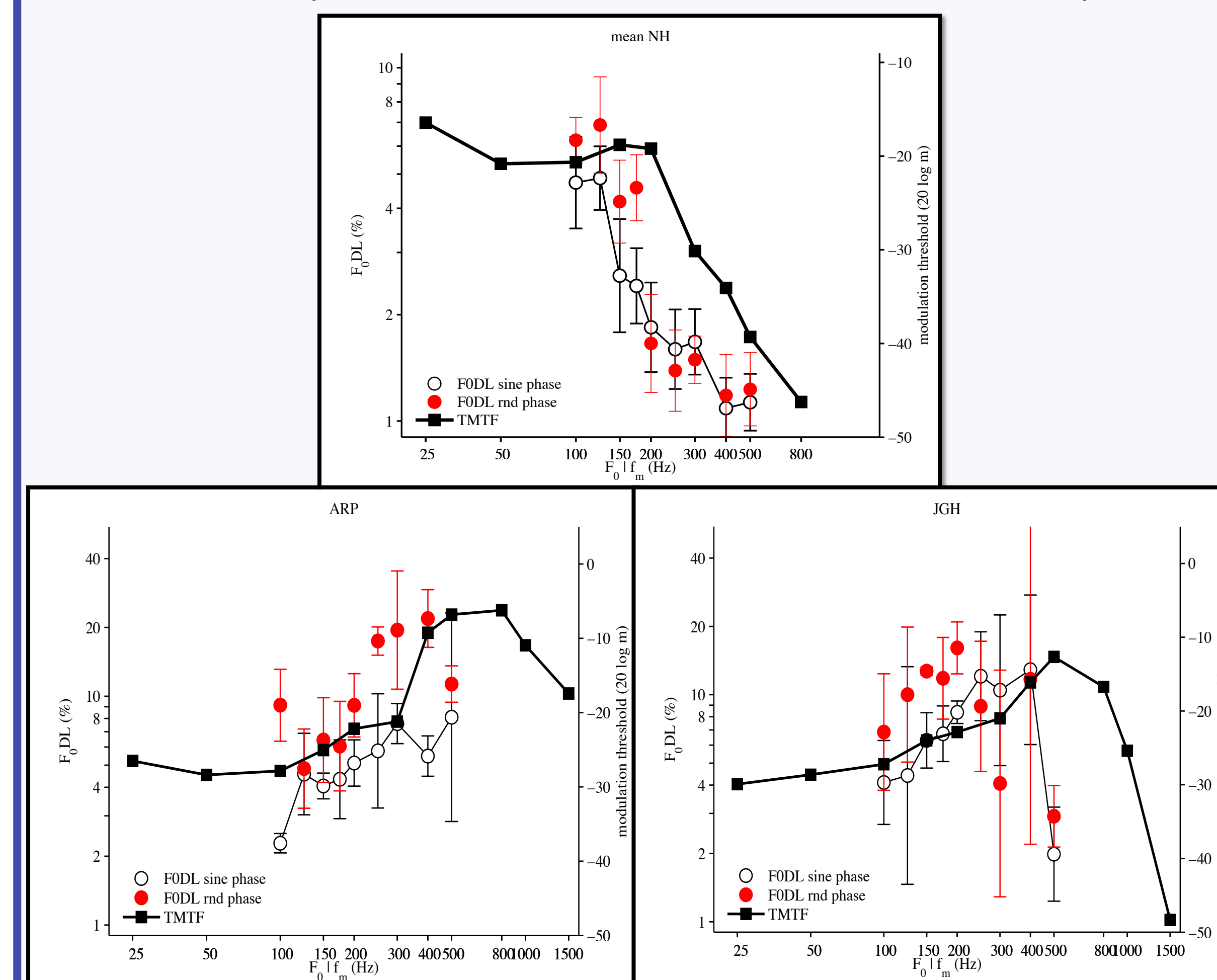


Figure 6. F_0 DLs (circles; left y-axis) compared to TMTF (black squares; right y-axis) for 4 NH (upper panel) and 2 HI listeners (lower panel).

Summary

- NH: performance in F_0 DLs improves with resolvability
- HI: large variability in F_0 DLs; resolvability did not imply better performance in F_0 DL.
- TMTF shows enhancement of envelope coding (not due to more components within the filter) for 2 HI listeners, who also show improved pitch discrimination abilities at low F_0 s.

Conclusion

- Resolvability alone could not explain the trend in F_0 DLs. Pitch discrimination of unresolved complex tones seemed to rely on temporal envelope cues (Kale et al., 2014): enhanced temporal coding was consistent with lower pitch discrimination thresholds and limitations in coding fast amplitude fluctuations was consistent with poor pitch discrimination.
- Future work: measure basilar membrane input/output function. Hypothesis: reduction of compression with SNHL should correlate with enhancement of envelope coding.

References:

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